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Canadian Science Advisory Secretariat
Science Advisory Report 2008/025

STATE OF THE OCEAN 2007: PHYSICAL OCEANOGRAPHIC CONDITIONS ON THE SCOTIAN SHELF, BAY OF FUNDY AND GULF OF MAINE

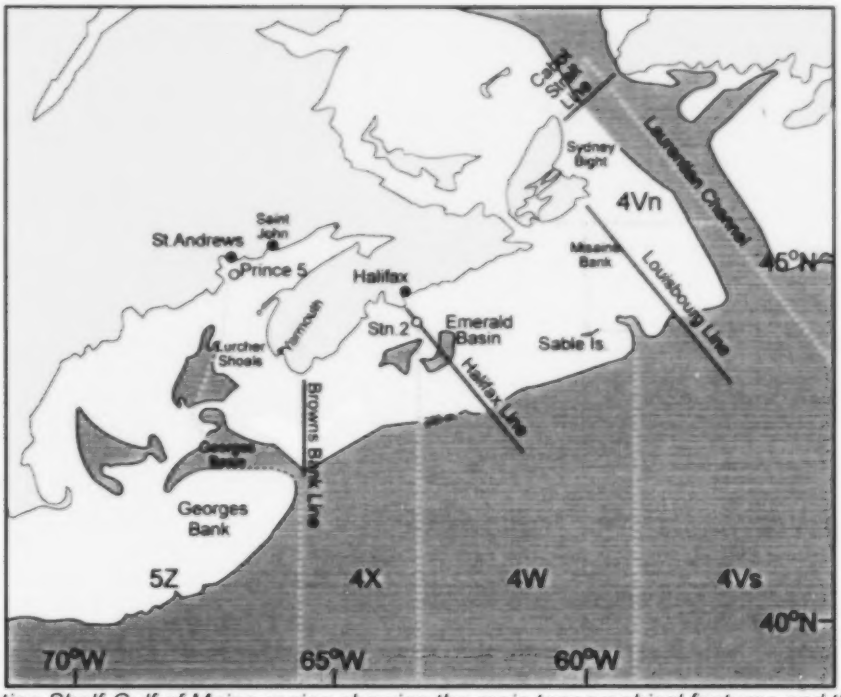


Figure 1. Scotian Shelf-Gulf of Maine region showing the main topographical features and the locations of AZMP monitoring sites and sections.

Context

The physical oceanographic environment influences the yield (growth, reproduction, survival), and behaviour (distribution, catchability, availability) of marine organisms as well as the operations of the fishing industry. Environmental changes may contribute directly to variations in resource yield, reproductive potential, catchability, year-class size (recruitment) and spawning biomass; they may also influence the perception of the resource status and the efficiency and profitability of the industry.

*Physical oceanographic conditions (mainly water temperature and salinity) are therefore measured during research vessel resource surveys and regularly at fixed sites as part of the **Atlantic Zone Monitoring Program (AZMP)**. Additional hydrographic, meteorological and sea ice data are obtained from a variety of sources, including standard monitoring stations, research studies, ships-of-opportunity, fishing vessels and remote sensing (satellites). A state of the ocean report is completed annually for each region of the Atlantic coast based on this information.*

All hydrographic data are edited and archived in Canada's national Integrated Scientific Data Management (ISDM) database. A working copy is maintained in a Northwest Atlantic database at the Bedford Institute of Oceanography.

June 2008

Canada

SUMMARY

- The North Atlantic Oscillation Winter Index was above normal after a weak, below normal value in 2006.
- Annual air temperatures over the Scotian Shelf, Bay of Fundy and eastern Gulf of Maine were about 0.2°C below normal, 1.3°C cooler than in 2006.
- Sea ice cover seaward of Cabot Strait was less than normal, but increased relative to 2006.
- Annual sea-surface temperatures in 2007 declined by 0.6°C to 2.3°C over the Scotian Shelf and eastern Gulf of Maine relative to the above normal values in 2006. Sea-surface temperatures remained above normal by about 0.3°C on the eastern and central Scotian Shelf, and Bay of Fundy and below normal by 0.5°C to 1.5°C elsewhere.
- Generally cooler (~1°C) than normal conditions prevailed in subsurface waters over the Scotian Shelf and eastern Gulf of Maine, a decrease of about 2°C from 2006. The cooling was in part caused by the replacement of warmer, more saline subsurface waters by Labrador Slope Water.
- Bottom temperatures during the July 2007 groundfish survey were about 0.8°C below normal, 1.5°C cooler than in 2006.
- Vertical stratification (0-50 m) for the Scotian Shelf remained higher than average, but slightly weaker than in 2006.

BACKGROUND

Temperature and salinity conditions in the Scotian Shelf, Bay of Fundy and Gulf of Maine regions are determined by heat transfer between the ocean and atmosphere, inflow from the Gulf of St. Lawrence supplemented by flow from the Newfoundland Shelf, exchange with offshore slope waters, local mixing, freshwater runoff, direct precipitation and melting of sea-ice. Water properties have large seasonal cycles, east-west and inshore-offshore gradients, and vary with depth (Petrie et al. 1996). Shelf topography is a major factor affecting the circulation. In this report, the reference period used for climate normals is 1971-2000.

ASSESSMENT OF CONDITIONS IN 2007

The North Atlantic Oscillation (NAO) is the dominant atmospheric pattern in the North Atlantic Ocean; it affects water properties and circulation through air-sea heat exchange and wind stress. In 2007, the NAO Winter Index was above normal (2.5 mb), an increase from the -3.3 mb anomaly in 2006 (Figure 2). Above normal NAO anomalies are generally accompanied by cooler than normal winter air temperatures leading to cooler than normal waters in the Labrador Sea. These waters can subsequently be transported into the Scotian Shelf-Gulf of Maine, affecting the region's ocean conditions.

Annual air temperatures over the Scotian Shelf and eastern Gulf of Maine were normal to 0.2°C below normal in 2007, ~1.3°C cooler than in 2006. The monthly anomalies in 2007 were generally cooler than normal early in the year but small for all months at Sable Island, Yarmouth and Saint John. Sable Island air temperature has a weak long-term increasing trend of about 1°C/century, amounting to 1°C over the length of the record (Figure 3).

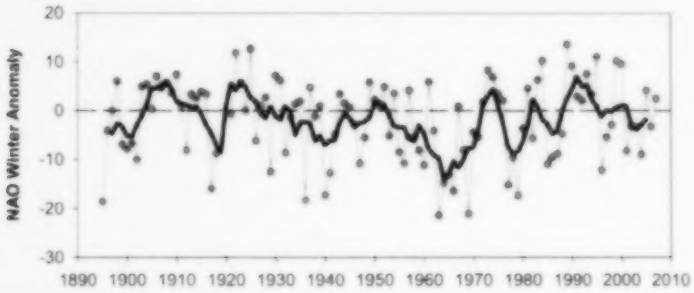


Figure 2. North Atlantic Oscillation winter anomaly relative to the 1971-2000 means. The annual anomaly (grey line with dots) and 5 year running means (black line) are shown.

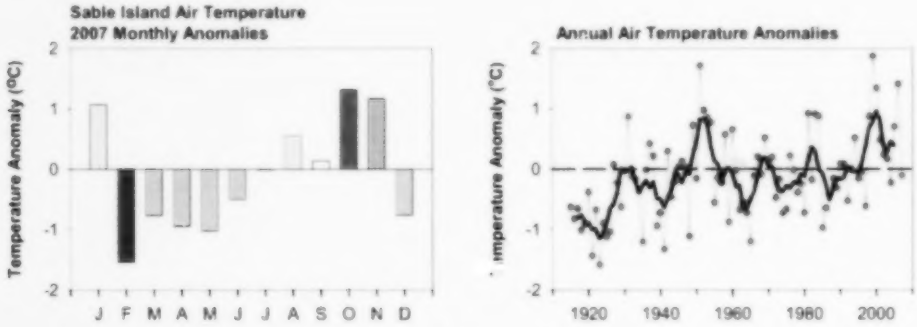


Figure 3. Sable Island monthly air temperature anomalies for 2007 relative to the 1971-2000 means (left panel). The colour of the bars represents the number of standard deviations the anomaly differs from the mean (see Figure 12). Time series of annual air temperature anomalies (grey line and dots) and 5 year running means (heavy, black line; right panel).

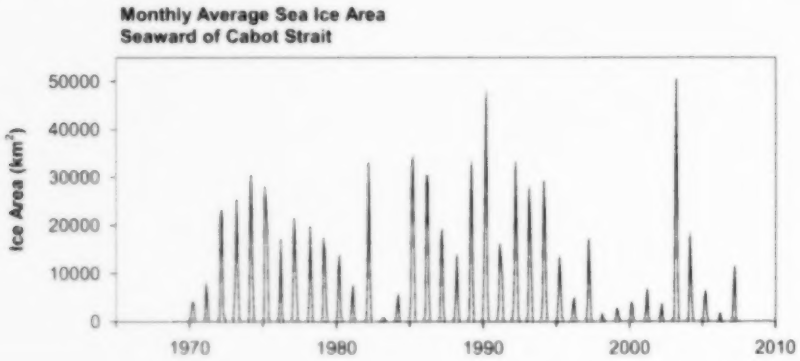


Figure 4. Time series of monthly average sea ice area seaward of Cabot Strait.

The January-April 2007 sea ice cover seaward of Cabot Strait was below normal but increased relative to 2006 (Figure 4). The coverage was 47% of the normal ice cover; 2007 ranked 15th lightest cover in the 39 year record.

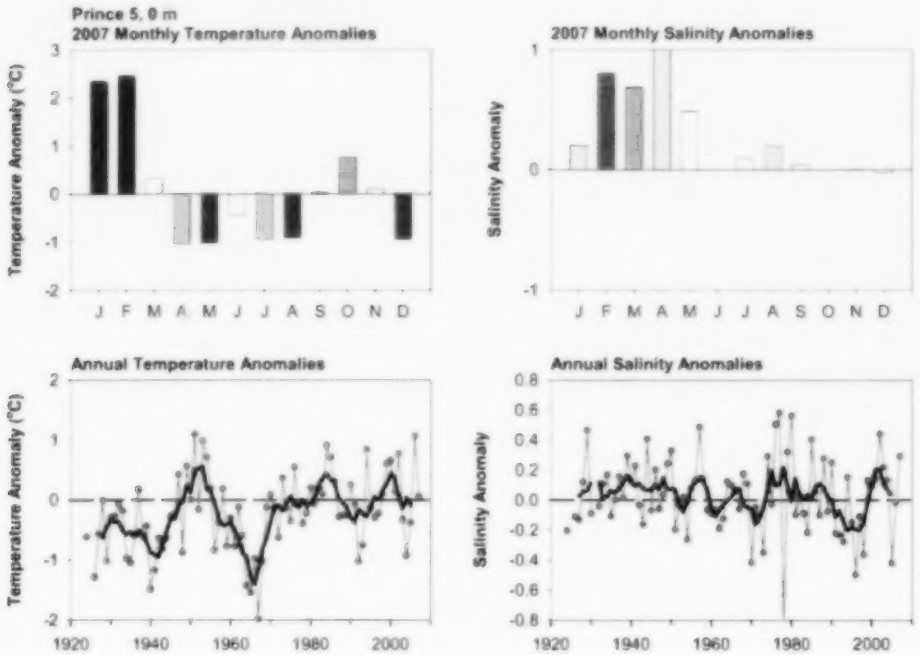

Prince 5, 0 m
2007 Monthly Temperature Anomalies
Temperature Anomaly (°C)
J F M A M J J A S O N D
2007 Monthly Salinity Anomalies
Salinity Anomaly
Annual Temperature Anomalies
1920 1940 1960 1980 2000
Annual Salinity Anomalies

Figure 5. Monthly surface temperature anomalies for 2007 relative to the 1971-2000 means for the Prince 5 station at the mouth of the Bay of Fundy (top left panel). The colour of the bars represents the number of standard deviations the anomaly differs from the mean (see Figure 12). Time series of annual surface temperature anomalies (grey line and dots, lower left panel) and 5 year running means (heavy, black line; lower left panel). Monthly surface salinity anomalies for 2007 (top right panel) and the time series of annual surface salinity anomalies (grey line and dots, lower left panel) and 5 year running means (heavy, black line; lower right panel).

The annual average sea-surface temperature (SST) in 2007 at St. Andrews, N.B. was normal, a decrease of 1.3°C from 2006, the warmest year of the 87 year record. At Halifax, the annual surface temperature anomaly was 1°C below normal, also a decrease of 1.3°C, and making 2007 the 11th coolest in 82 years. At Prince 5, monthly average temperatures were substantially above normal for January and February but generally cooler for the remainder of 2007 (Figure 5). This led to annual anomalies of less than 0.1°C at the surface and bottom, i. e. near normal values. Temperatures decreased by about 1.1°C relative to 2006. The monthly salinities were dominated by large positive anomalies from February to April. Annual averages were ~0.3 above normal at the surface and ~0.1 above normal at 90 m (Figure 5). Satellite based observations indicate below normal SST over the western Scotian Shelf (-1.5°C), Lurcher Shoals (-1°C) and Georges Bank (-0.5°C), and above average values over the eastern and central Scotian Shelf, and the Bay of Fundy (all by 0.3°C).

In the Laurentian Channel to the east of the Scotian Shelf, temperatures in the deep (200-300 m) waters of Cabot Strait in 2007 were 0.2°C below the long-term mean, a decrease of ~0.2°C from the 2006 observation. In Emerald Basin, the temperatures from 0 to 20 m were about 0.3°C below normal (Figure 6). The anomalies from 30 to150 m were nearly constant at about -1.1°C, and decreased to -1.8°C at 250 m. The overall decrease of ~2°C from surface to bottom in the Basin from 2006 to 2007 resulted from an inflow of Labrador Slope Water. This is very evident when temperature and salinity properties in the Basin and over the upper continental slope are compared to the definitions of water mass properties.

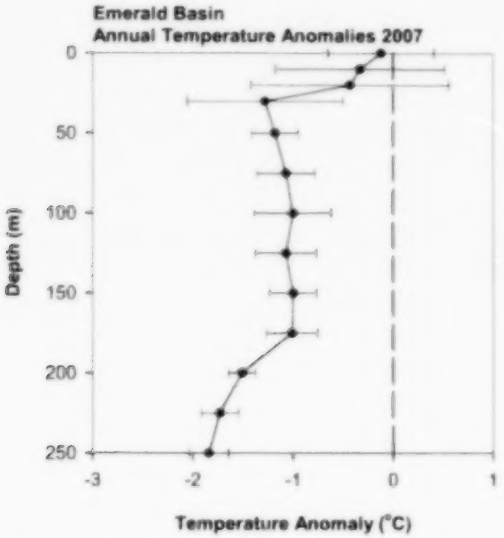


Figure 5. Depth profile of the annual temperature anomalies (dots) based on averages of the monthly anomalies for Emerald Basin in 2007. Horizontal bars are estimates of the standard error.

Temperature anomalies over the Scotian Shelf and eastern Gulf of Maine during the 2007 July groundfish survey varied with depth but, except for the surface layer, the overall pattern was dominated by negative anomalies (Figure 7). At the surface, temperatures were above normal by as much as 4°C over the eastern half of the shelf. At 50 m, most of the Scotian Shelf had below normal temperatures, generally by 0-1°C. The anomaly patterns at 100 m and at the bottom were similar to the one at 50 m: the largest negative anomalies were foumd in the western half of the Shelf, with values to -2°C.

The average bottom temperature for the area covered in the 2007 July groundfish survey was about 5.0°C, about 0.8°C below the 1971-2000 mean temperature; this makes 2007 the 5th coldest in 38 years and only 0.5°C warmer than 2004, the year with the coldest bottom temperatures over the entire time series (Figure 8). This is a decrease of 1.5°C from 2006.

The spring oceanographic survey of the Cabot Strait, Louisbourg, Halifax and Browns Bank lsections found that negative temperature anomalies dominated, with magnitudes of ~1°C over the Shelf but as large as -6°C over the shelf break (Figure 9). Below normal salinities accompanied the colder than normal temperatures. In October, negative anomalies continued to dominate all sections, especially over the Shelf. The shelf break anomalies had decreased on the Louisbourg and Halifax sections, and had been replaced by positive anomalies at Browns Bank. An examination of the temperature and salinity relationships from these sections indicated that the water mass characteristics on the outer stations were largely those of Labrador Slope Water. Moreover, as noted above, these waters had penetrated onto the Shelf and were particularly evident in Emerald Basin. They were also found on the western Scotian Shelf, Lurcher Shoals and the eastern Gulf of Maine. The dominance of Labrador Slope Water accounts for the negative temperature and salinity anomalies. This was the first major penetration of Labrador Slope Water onto the Shelf since 1998. That event lasted one year before the Labrador Slope Water was replaced by Warm Slope Water.

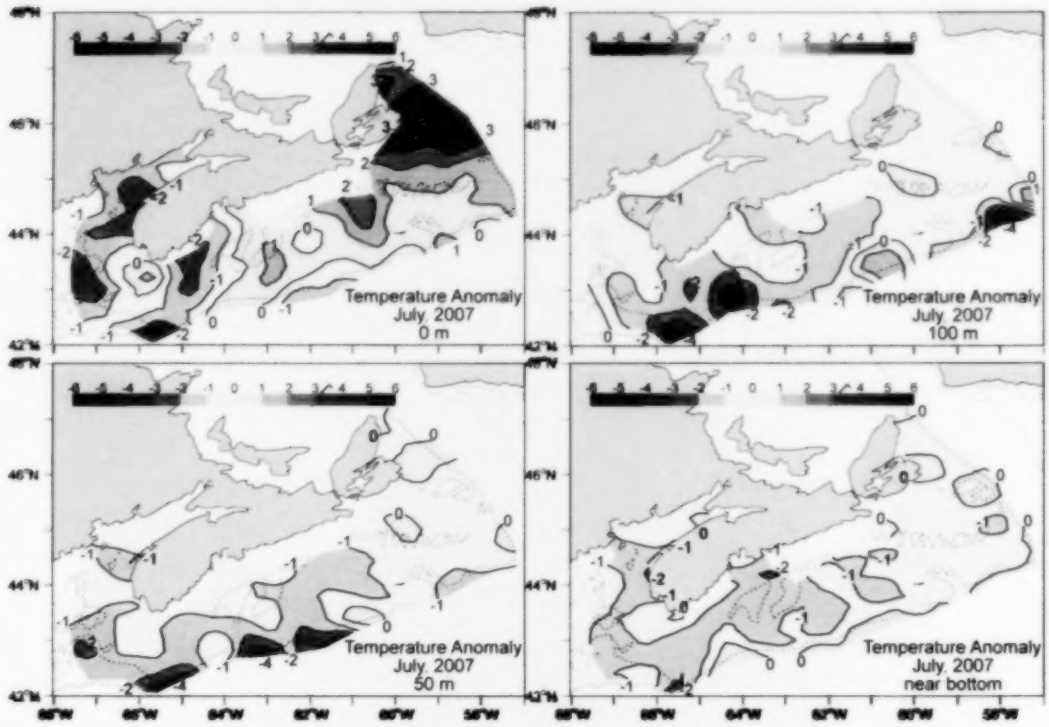


Figure 7. Plan views of the temperature anomalies at 0, 50, 100m and near the bottom for the Scotian Shelf in July 2007. The anomalies are based on observations collected during the annual groundfish survey.

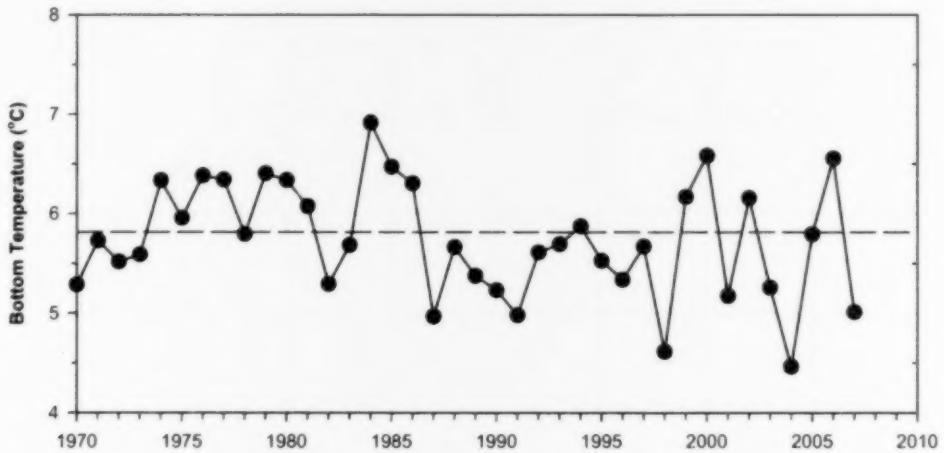


Figure 8. Time series of the average bottom temperature for the Scotian Shelf based on data from the annual July groundfish survey. The broken line is the 1971-2000 mean.

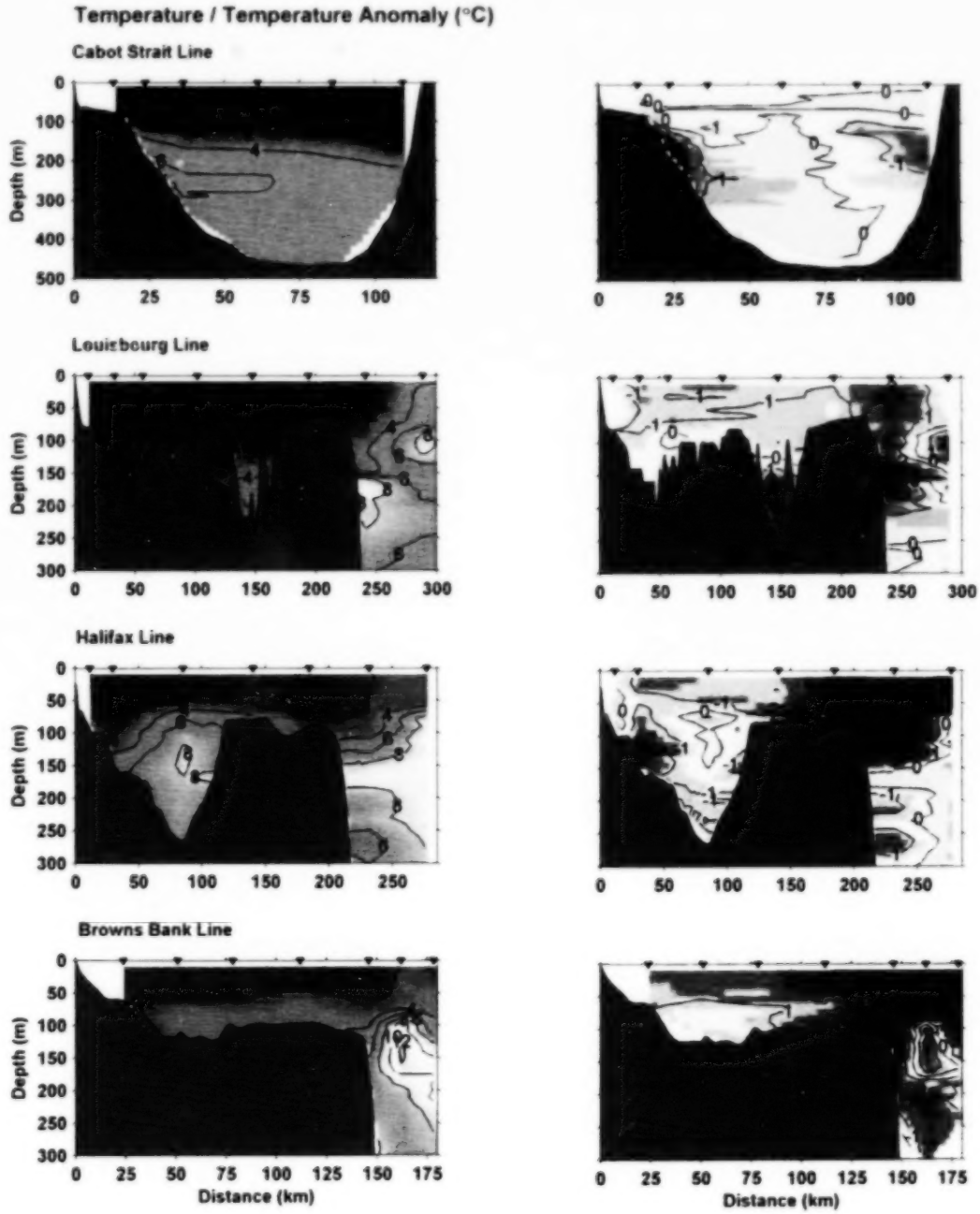
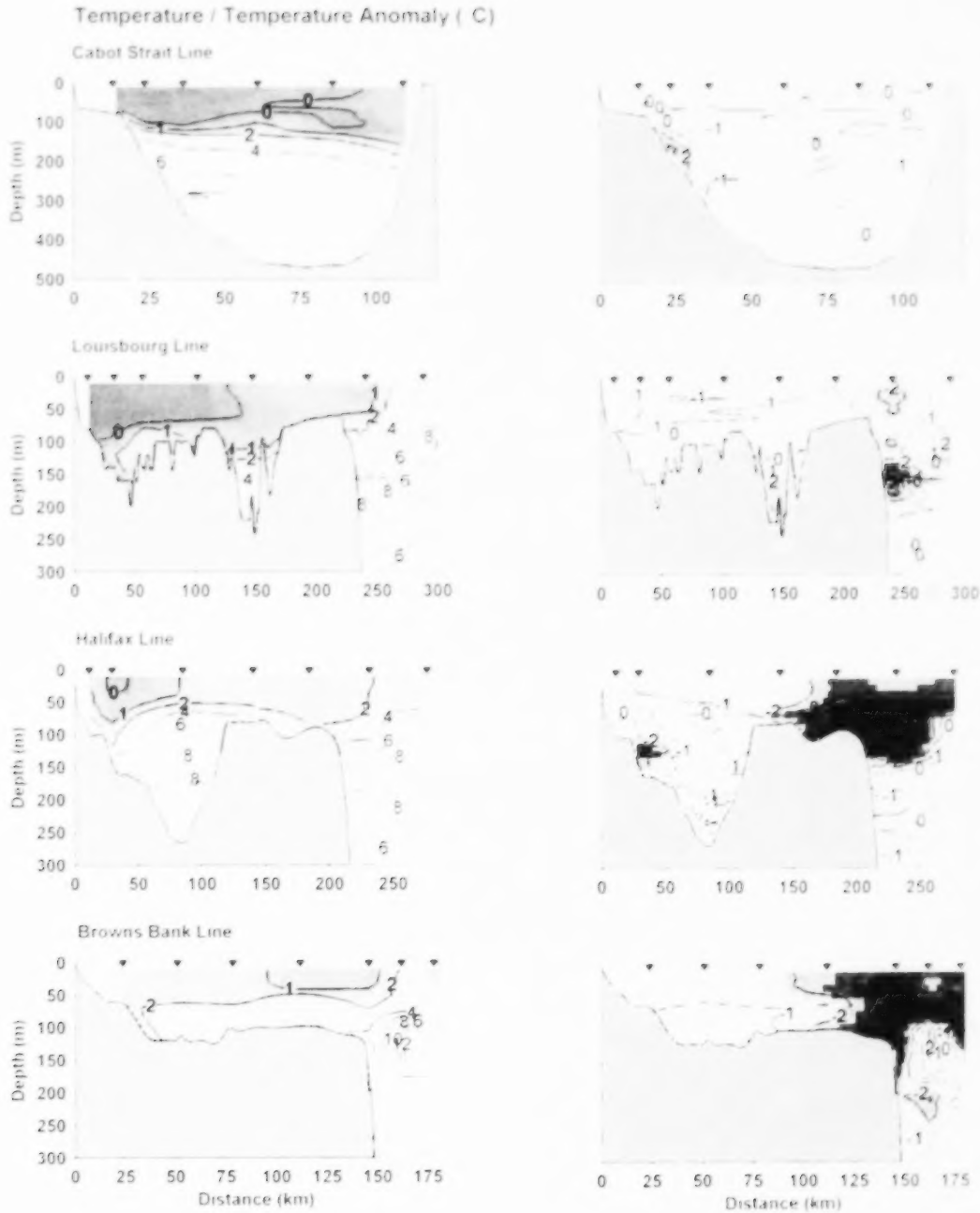


Figure 9. April 2007 temperature (left panels) and temperature anomaly (right panels) sections from Biological Ocean Science's spring survey of the Scotian Shelf. Below (above) normal temperatures are shaded blue (red) in the left hand panel.

In 2007, annual temperature anomalies in Sydney Bight (100 m), Misaine Bank (100 m), Emerald Basin (250 m), Lurcher Shoals (50 m), Georges Basin (200 m) and eastern Georges Bank (50 m) were 0.2, -0.3, -1.8, -1.8, -0.8 and -0.7°C respectively (Figure 10). The overall tendency featured weak anomalies in the northeastern sector of the Scotian Shelf changing to strong negative anomalies over the central and western Shelf, in Georges Basin, and on Georges Bank.



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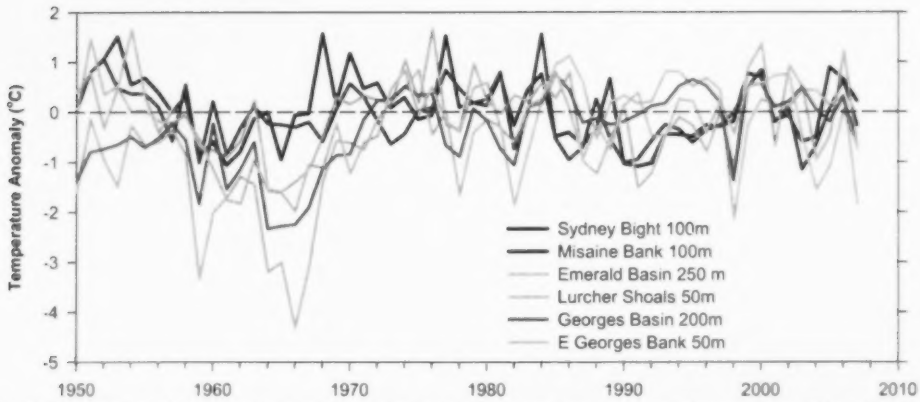

Figure 10. Time series of annual ocean temperature anomalies from various sites (Fig. 1) on the Scotian Shelf and in the Gulf of Maine.

Seawater density depends on temperature, salinity and pressure and increases with depth in the ocean. The density difference between waters at two depths is referred to as the density stratification. The density stratification divided by the depth difference is called the stratification index. In the 1990s, the average 0 to 50 m index over the Scotian Shelf increased significantly. From the mid to late 1990s, the index was at or near its maximum over the 50-year record (Figure 11). Increased stratification inhibits vertical mixing, can decrease nutrient fluxes to the surface waters and thus decrease phytoplankton production. In 2007, stratification decreased slightly from its 2006 value, but remained higher than average; the index, which is compiled for 19 areas over the Shelf, was quite uniform in 2007 as 15 of the areas had positive anomalies.

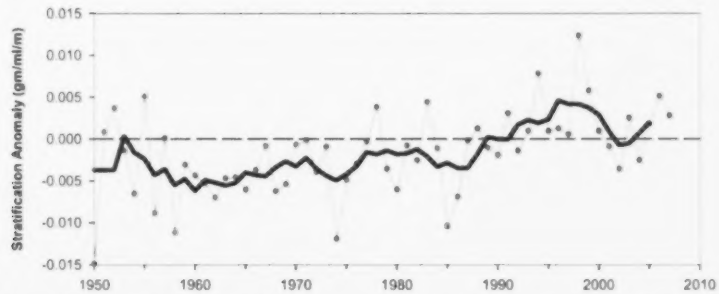

Figure 11. Time series of the density stratification anomaly over the Scotian Shelf. The annual anomaly (grey line, dot) and 5 year running means (black line) are shown.

The average position of the temperature boundary between shelf and slope waters (Shelf/Slope front) was south of its long-term mean position by about 30 km in 2007; the boundary between slope and Gulf Stream waters was within 1 km of its long-term mean.

CONCLUSIONS

Year to year, water temperatures on the Scotian Shelf and in the Gulf of Maine are among the most variable in the North Atlantic Ocean. Moreover, within the region, some areas may experience above normal, others normal, and still others below normal ocean temperature anomalies in the same year. A summary of many of the time series already shown indicates the year to year and within year variability (Fig. 12). The results are displayed as the number of standard deviations (SD) above (red) and below (blue) normal; the deeper tints represent

greater deviations from normal. White cells are within 0.5 SD of normal. Annual anomalies are calculated using 1971-2000 as the reference period for the mean values and the standard deviations; individual anomalies for each variable have been normalized by dividing by its standard deviation.

Figure 12 illustrates the temporal and spatial variability in the region. For example, the periods 1987-1993 and 2003-2004 were predominantly colder than normal while 1999-2000 was warmer than normal. From 1979 to 1986, temperatures tended to be warmer than normal but, except for 1984, not as dominantly so as 1999-2000. In 2006, 16 of the 18 variables had values that were at least 0.5 standard deviations above normal; the composite index, the sum of all the normalized anomalies in Figure 12, is the highest of the 38 year time series. In 2007, 9 variables had normalized anomalies <-0.5 SD, 7 ranged from -0.5 to 0.5 SD, and 2 were >0.5 SD. Based on the composite index, 2007 ranked as the 7th coldest in 38 years; this is down significantly from 2006, when the index was at its highest.

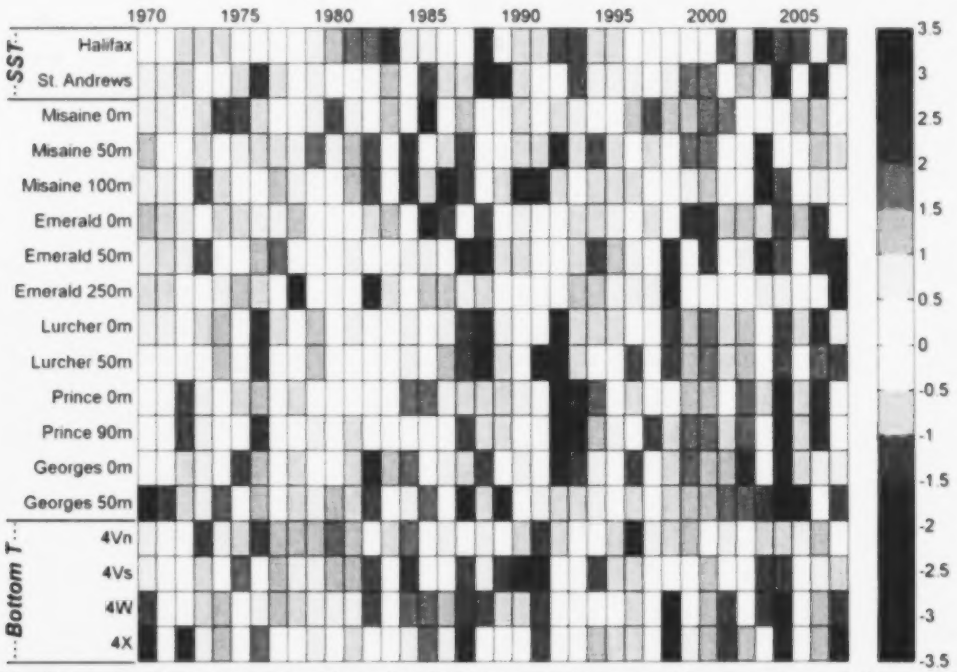

Figure 12. Normalized annual anomalies of bottom temperatures and temperatures at discrete depths for the Scotian Shelf-Gulf of Maine region. The normalized anomalies are the annual anomalies based on the 1971-2000 means, divided by the standard deviation. The scale represents the number of standard deviations an anomaly is from normal; blue indicates below normal, red above normal.

SOURCES OF INFORMATION

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ISSN 1480-4913 (Printed)
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CORRECT CITATION FOR THIS PUBLICATION

DFO. 2008. State of the Ocean 2007: Physical Oceanographic Conditions on the Scotian Shelf, Bay of Fundy and Gulf of Maine. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/025.